Stone Barn Dye Trace Report
Fillmore County, Minnesota

Traces:
19 March 2004

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Introduction

In the karst region of southeast Minnesota, water tracing of surface and groundwater using dyes has proven to be an effective method to understand water flow, travel times and the interconnections of water at the surface (streams, creeks, etc.) with groundwater. This technique has been used to map groundwater and surface water springsheds. A springshed is an area within groundwater and surface water basin that contributes discharge to a spring (or set of springs) and its delineation involves determining the size and nature of that land area. This area can encompass both a contributing surface watershed and an underlying groundwatershed and understanding its extent is important for the protection of the numerous trout fisheries and other ecosystems in SE MN and elsewhere. Additionally, water management associated with increasing agriculture, water demands, climate change, and landscape alteration requires efficient means of defining springsheds. The boundaries of groundwater springsheds do not necessarily correspond to those on the land surface and are dynamic in their areal extent, changing as groundwater levels rise and fall. In the current study, as a part of the statewide effort to delineate springsheds, two dye traces were conducted near Chatfield, MN in northern Fillmore County as part of the Minnesota Springshed Mapping Project (Figure 1).

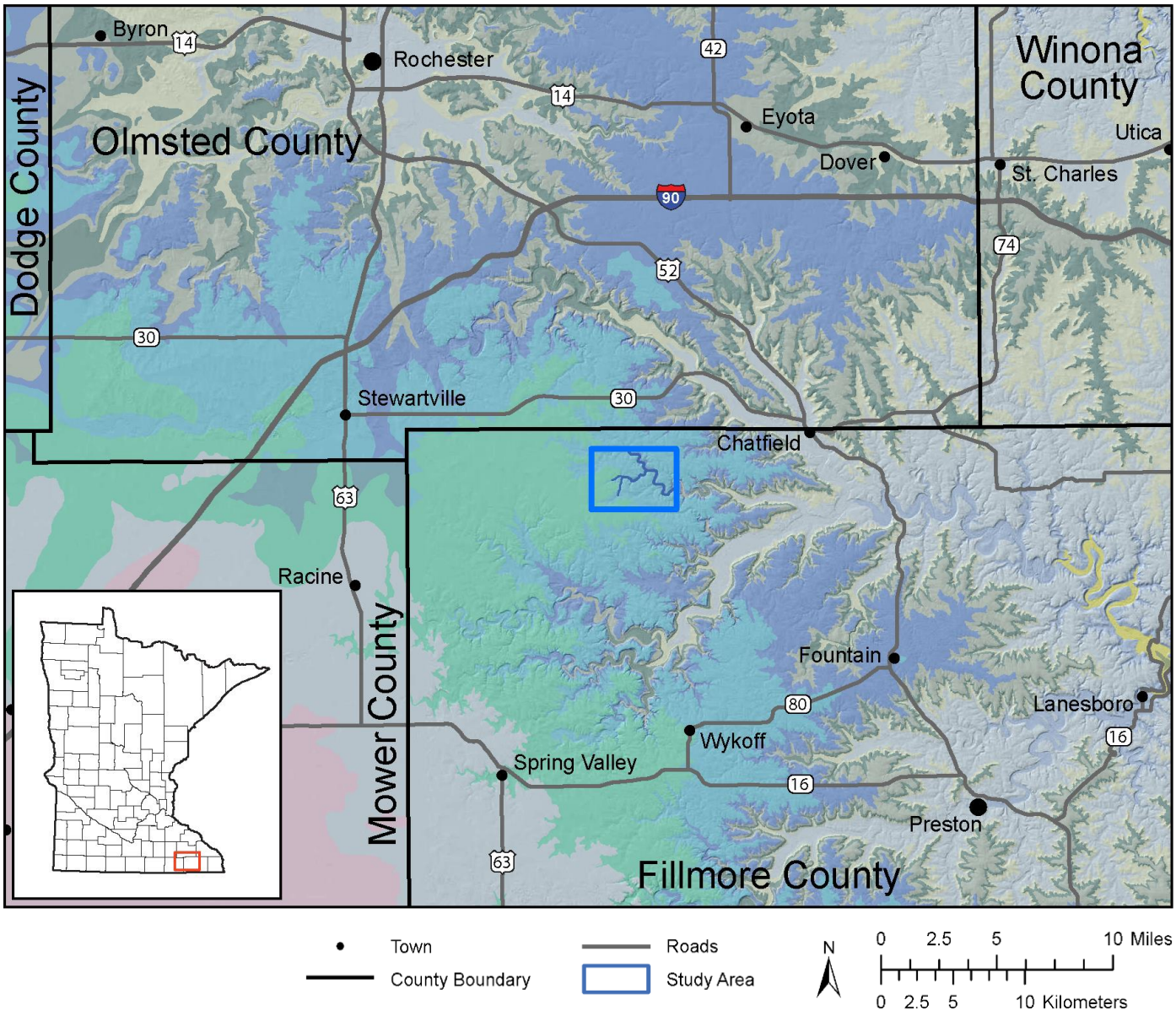

Figure 1. *Location of the Stone Barn study area. Shading corresponds with lithologies units in Figure 2.*

Fillmore County has abundant exposures of bedrock from Upper Cambrian through Devonian age capped by unconsolidated Ctretaceous and Quaternary unconsolidated sediments such as loess, sand, and colluvium (Mossler, 1995). The surface topography is comprised of flat upland plateaus mostly underlain by resistant limestones and

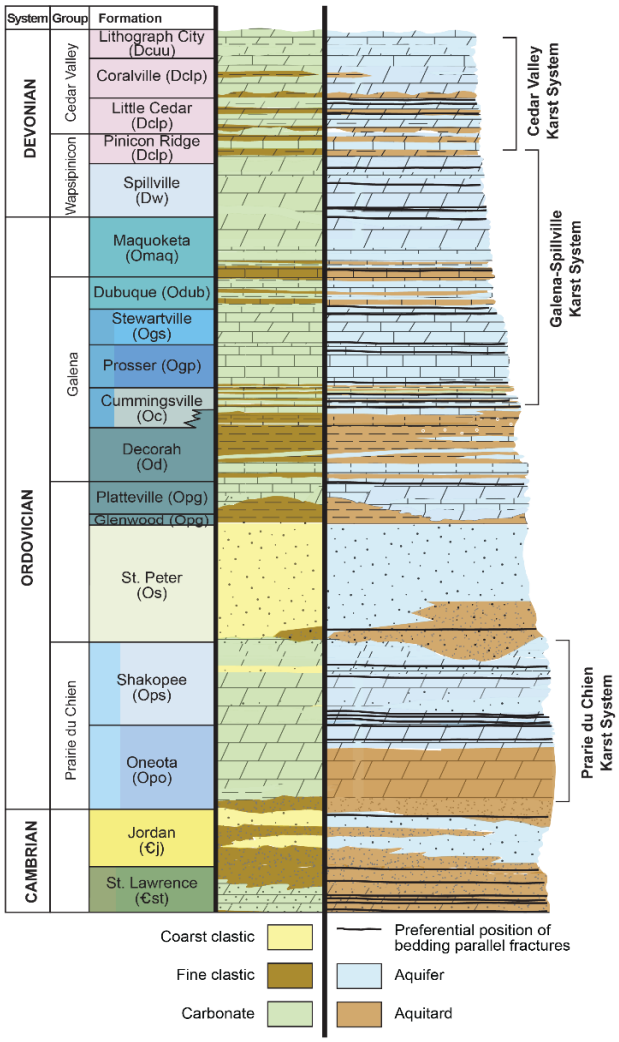

Figure 2. *Geologic and hydrogeologic attributes of Paleozoic rocks in southeastern Minnesota. Modified from Runkel et al. 2013. The current study features traces from the Maquoketa and Dubuque formations of the Middle Galena-Spillvile Karst System and resurge near the Dubuque – Stewartville contact.*

dolostones of the Galena Group, the Maquoketa Formation, and the Wapsipinicon and Cedar Valley Groups (Mossler and Hobbs, 1995). This upland landscape is dotted with sinkholes that allow surface water to drain through subsurface joints and conduits that have been enlarged by dissolution. Emergences often occur along spring lined bluff walls and meander scars (Mossler and Hobbs, 1995). A generalized geologic stratigraphic column for Fillmore County (Figure 2) shows lithostratigraphic and hydrostratigraphic properties for each of the units (modified from Runkel et. al. 2013). Hydrostratigraphic attributes have been generalized into either aquifer or aquitard based on their relative permeability. Layers assigned as aquifers are permeable and easily transmit water through porous media, fractures or conduits. Layers assigned aquitard have lower permeability that vertically retards flow, effectively hydraulically separating aquifer layers. However, layers designated as aquitards may contain high permeability bedding plane fractures conductive enough to yield large quantities of water. The current trace starts in the Maquoketa and Dubuque Formations and emerges near their basal contact with the Stewartville Formation. The Galena-Spillville Karst Sytem is in general characterized by rapid surface water infiltration into the upper carbonate units with travel rates ranging from hours to days per mile. Flow in the relatively impermeable Maquoketa and Dubuque Formations often occurs as horizontal flow via bedding plane

conduits before reaching the top of the Stewartville Limestone which is known to have prominent vertical joints enhanced by dissolution (Alexander and Lively, 1995).

Methods

Dye tracing entails using fluorescent dyes to track groundwater flow directions and estimate travel times. The dye is poured into a sinkhole or sinking stream. From there it flows through the karst conduit system until it re-emerges at a spring or multiple springs. For this project, two fluorescent dyes, Fluorescein and Rhodamine WT, were used to distinguish between the two input points. The locations of the dye input points and sampling locations are shown in Figure 3.

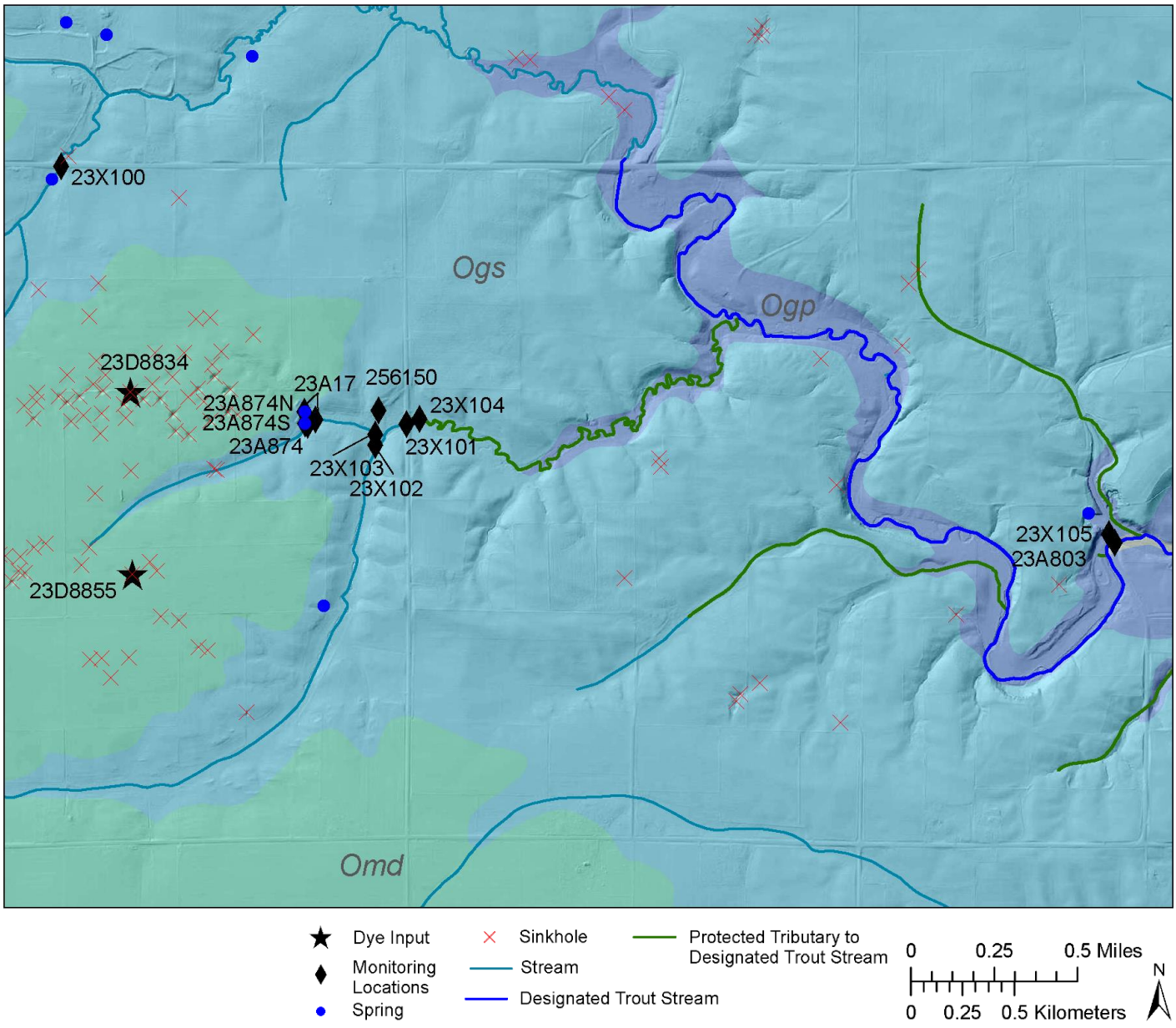

Figure 3. *Location of passive samplers and springs for the Stone Barn Study Area. Green shading represents that Maquoketa and Dubuque Formations while the blue shading represents the Stewartville Formation and the Prosser Formation (dark blue).*

The water source for these traces was snowmelt runoff and the dye was poured into the runoff stream as it flowed into the two selected sinkholes. Sampling points consisted of passive charcoal "bugs" that are designed to absorb fluorescent dyes should they flow past the detector which were placed at various springs and local stream locations. After collection,

bugs are then bathed in a NaOH eluent solution that strips the dye from the charcoal so the solution can be analyzed qualitatively. Each dye is characterized by a unique emission wavelength and can thus be distinguished from other dyes used in the study using resultant spectra curves fitted using PeakFit v.4.0 software. Analyses were performed at the University of Minnesota Earth Sciences Department Hydrochemistry Laboratory using a Shimadzu RF5000U scanning spectrofluorophotometer.

Results and Discussion

The two dyes flushed successfully into Sinkholes 23D8834 and 23D8855 and were both detected at spring 23A17 (the impoundment outfall) and at the residential well (MN Unique No. 256150). The well is the original drinking water source at this site and is 60 feet deep and completed in the karsted Ordovician Stewartville Formation. Transit time for both traces is estimated to be approximately less than five days. Results from the dye traces are shown in Figure 4 with inferred groundwater flow vectors. Charcoal detector and water sample analysis results are listed in the Table Appendices.

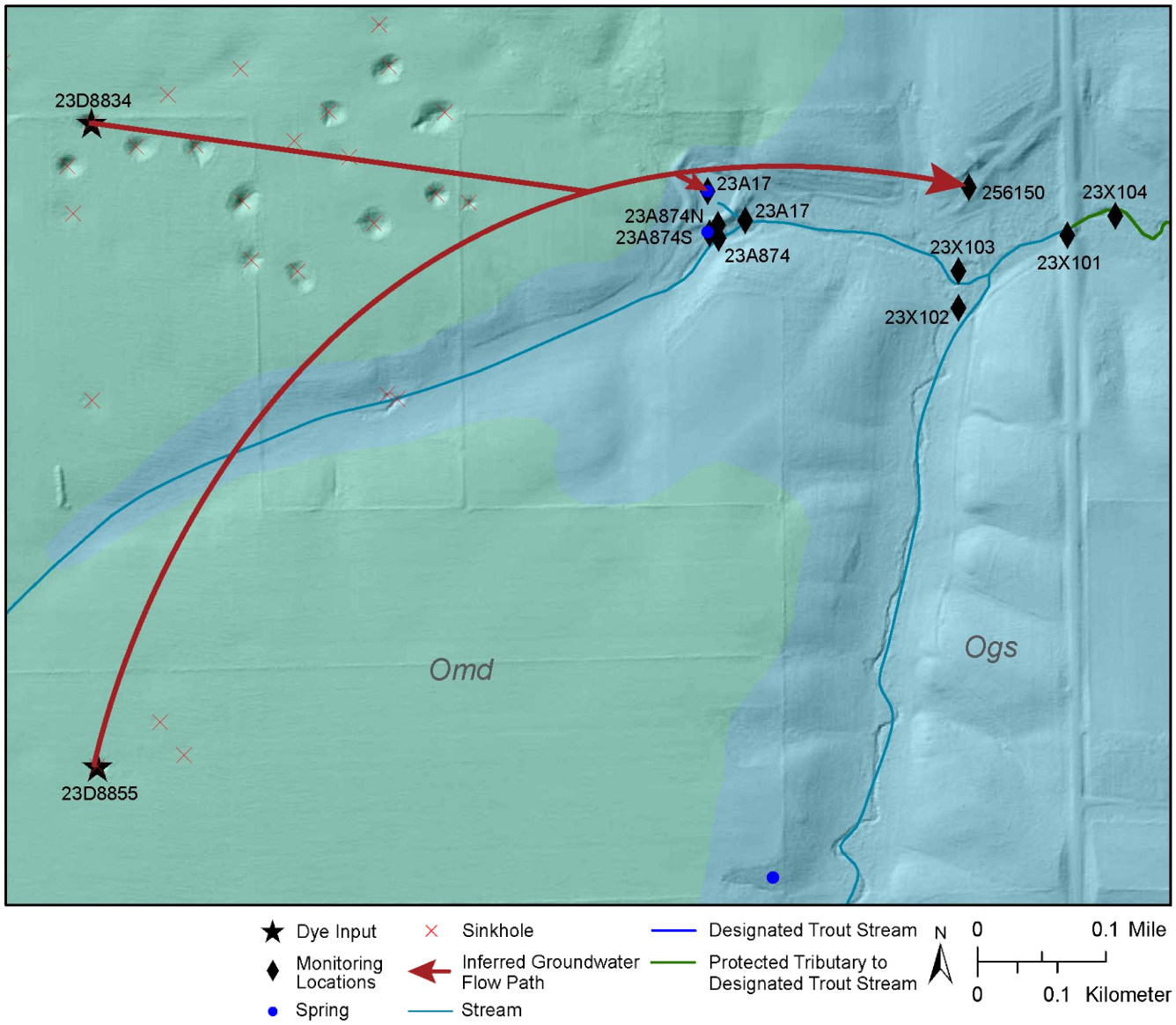

Figure 4. *Dye input locations, sampling points and inferred groundwater flow paths. Green shading represents the Maquoketa and Dubuque Formations while the blue shading represents the Stewartville Formation.*

Conclusions

This successful trace delineates, at least in part, the groundwater springshed that feeds spring 23A17 and spring 23A874. It also demonstrates potential impacts that the contributing land and groundwater area could have on potable water from the nearby residential well. However, the lateral extent of this springshed is not a sharp boundary and can move dynamically, both horizontally and vertically, in response to recharge events. The presence of other sinkholes in the area would allow for further traces to be done in order to refine and expand the groundwater springshed boundaries of springs 23A17 and 23A874. Understanding the contributing areas that feed springs is important for understanding and protecting their water quality and maintaining an important natural resource.

Acknowledgments

The authors would like to thank the landowners, Gary and Deb Anderson, for allowing this trace to occur on their property. This work was partially funded by the Fillmore Soil and Water Conservation District local water planning grant.

References

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Table Appendices
Stone Barn Traces 19 March 2004 (2 Traces)

Carbon (Bug) Analysis Results

Trace Input Date: 19 March 2004

Trace Input Location 1: 23D0008834 - 339.9 gm of 20 wt% sol. Rhodamine WT @ 12:00 19 Mar 2004

Trace Input Location 2: 23D0008855 - 499.2 gm of 35 wt% sol. Fluorescein (uranine) @ 12:30 19 Mar 2004

Field Personnel at Inputs and/or Sampling: Jeffrey A. Green, E. Calvin Alexander Jr., Scott Alexander

Property Owners: Gary & Deb Anderson Rt. 1, Box 152 Chatfield, MN 55923 (507)867-4692

CHARCOAL DETECTORS

fluor = fluorescein (~ 515 nm)	amp. = fluorescent amplitude
eos = eosin (~ 539 nm)	cent. = peak center (nanometers = nm)
RhWT = Rhodamine WT (~ 565)	fwhm = full width half maximum (nm)
SrhB = sulforhodamine B (~ nm)	nd = no dye detected
unkn = unknown peak	off scale = strong positive

KFDB#	Field Site	In		Out		results	amp.	cent. (nm)	fwhm (nm)	area
		Date	time	Date	time					
23X0000100	Road culvert north side of sec. 7, Jordan Twp. Down stream of A812	23 Feb 2004	8:45	08 Mar 2004	10:00	nd				
		08 Mar 2004		19 Mar 2004	11:30	nd				
		19 Mar 2004	11:30	24 Mar 2004	12:00	nd				
		24 Mar 2004	10:00	31 Mar 2004	11:30	nd				
23X0000101	West end of road culvert east side of sec. 7, Jordan Twp. Down stream of A17, A804 & A874	23 Feb 2004	8:45	08 Mar 2004	10:00	nd				
		08 Mar 2004		19 Mar 2004		nd				
		19 Mar 2004	11:30	24 Mar 2004	12:00	fluor	51	514.4	20.2	1
23X0000102	Stream run down stream of A804, sec. 7 Jordan Twp.	28 Feb 2004		19 Mar 2004	11:30	nd				
		19 Mar 2004	11:30	24 Mar 2004	12:00	nd				
		24 Mar 2004	11:15	31 Mar 2004	11:00	nd				
23X0000103	Stream run down stream from A17 & A874, sec. 7, Jordan Twp.	26 Feb 2004		19 Mar 2004	11:30	nd				
		19 Mar 2004	11:30	24 Mar 2004	12:00	fluor	3.0	514.8	30.8	109
		24 Mar 2004	11:15	31 Mar 2004	11:00	fluor	335	513.9	19.8	7211
23X0000104	East end of road culvert west side of sec. 8, Jordan Twp. Down stream of A17, A804 & A874	24 Mar 2004	11:00	31 Mar 2004	10:45	fluor	245	514.4	19.8	5280
23X0000105	Bear Creek Culvert, west end, sec. 9, Jordan Twp. Down stream of everything	19 Mar 2004	11:30	24 Mar 2004	12:00	fluor	346	514.7	20.1	7570
						RhWT	12	563.6	25.7	329
		24 Mar 2004	11:45	31 Mar 2004	12:00	fluor	19	514.5	20.4	431
23A0000017	Spring A17, Stone Barn Spring. Monitored at end of outfall pipe through dam.	28 Feb 2004		19 Mar 2004		nd				
		19 Mar 2004	11:30	24 Mar 2004	12:00	fluor	1100	514.6	19.7	29509
						RhWT	28	565.2	23.1	724
		24 Mar 2004	10:45	31 Mar 2004	11:15	fluor	1386	514.6	19.6	23315
						RhWT	13	561.0	29.6	420
23A0000803	Spring Run from A803, sec. 9, Jordan Twp. Near X105.	24 Mar 2004	12:00	31 Mar 2004	12:00	nd				
23A0000874	Spring A874. Spring at the southwest end of the dam impounding A17. Monitoring point down stream from spring. Labeled "A17X"	19 Mar 2004	11:30	24 Mar 2004	12:00	RhWT	1.2	561.0	22.3	30
		24 Mar 2004	10:30	31 Mar 2004	11:15	nd				

WATER SAMPLES

fluor = fluorescein (~ 507 nm)	amp. = fluorescent amplitude
eos = eosin (~ 531 nm)	cent. = peak center (nanometers = nm)
RhWT = Rhodamine WT (~ 570 nm)	fwhm = full width half maximum (nm)
SrhB = sulforhodamine B	nd = no dye detected
ukn = unknown peak (see notes)	*** = no sample

ID#	Name	Date	time	results	amp.	cent. (nm)	fwhm (nm)	*area diluted*	area	ppb
23X0000100	Road culvert north side of sec. 7, Jordan Twp. Down stream of A812	20-Mar-04	9:30	nd						
		24-Mar-04	10:15	nd						
		31-Mar-04	11:30	nd						
23X0000101	West end of road culvert east side of sec. 7, Jordan Twp. Down stream of A17, A804 & A874	20-Mar-04	10:00	nd						
		22-Mar-04	11:00	fluor	78	506.7	20.0		1697	
				RhWT	6	570.2	23.5		163	
		24-Mar-04	11:10	fluor	54	507.0	19.9		1166	
				RhWT	4	570.5	23.3		92	
		31-Mar-04	11:00	fluor	13	506.9	20.2		283	
				RhWT	1.1	570.2	21.3		26	
23X0000102	Stream run down stream of A804, sec. 7 Jordan Twp.	20-Mar-04	10:00	nd						
		22-Mar-04	11:00	nd						
		24-Mar-04	11:15	nd						
		31-Mar-04	11:00	nd						
23X0000103	Stream run down stream from A17 & A874, sec. 7, Jordan Twp.	22-Mar-04	11:30	fluor	25	506.7	19.9		538	
		24-Mar-04	11:20	fluor	52	506.8	19.9		1122	
		31-Mar-04	11:00	fluor	25	506.8	20.0		555	
23X0000104	East end of road culvert west side of sec. 8, Jordan Twp. Down stream of A17, A804 & A874	24-Mar-04	11:00	fluor	59	507.0	19.9		1287	
				RhWT	3.6	570.7	23.3		91	
		31-Mar-04	10:45	fluor	11	507.0	20.5		238	
				RhWT	0.8	570.7	23.3		91	
23X0000105	Bear Creek Culvert, west end, sec. 9, Jordan Twp. Down stream of everything	24-Mar-04	11:45	nd						
		31-Mar-04	12:00	nd						
0000256150	Anderson house well, original well, 60' deep. Unique # 256150	22-Mar-04	11:00	fluor	502	506.9	19.7		10742	
				RhWT	6	570.0	22.2		157	
		31-Mar-04	11:30	fluor	502	506.9	19.7		10742	
				RhWT	3.3	570.9	22.2		81	
23A0000017	Spring A17, Stone Barn Spring. Monitored at end of outfall pipe through dam.	24-Mar-04	10:30	fluor	61	507.2	20.7		1377	
				RhWT	4.3	570.8	22.9		108	
		31-Mar-04	11:15	fluor	9	507.2	20.5		192	
				RhWT	2.1	570.4	23.2		53	
23A0000803	Spring Run from A803, sec. 9, Jordan Twp. Near X105.	24-Mar-04	12:00	nd						
		24-Mar-04	12:15	nd						
		31-Mar-04	12:00	nd						
23A0000874	Spring A874. Spring at the southwest end of the dam impounding A17. Monitoring point down stream from spring. Labeled "A17X" initially.	20-Mar-04	9:45	nd						
		20-Mar-04	9:45	nd						
		22-Mar-04	11:15	nd						
		24-Mar-04	10:30	nd						
		31-Mar-04	11:15	fluor	2	506.9	20.7		37	